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The Effects of Mental Workload: Soldier Shooting and Secondary Cognitive Task Performance

by David R. Scribner and William H. Harper

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14. ABSTRACT

The dismounted Soldier of the future will be "loaded" with more information processing tasks while performing shooting tasks. It is imperative that the Soldier not be overburdened mentally to preserve maximal survivability and lethality.
The present study proposed the examination of the ability of the Soldier or Marine to perform various cognitive tasks like decision-making, mental calculations, and a memory recall task while engaged in friend-or-foe shoot-don't shoot scenarios. The secondary tasks consisted of mathematical problem solving and situational awareness (SA) memory recall tasks. Participants were 16 U.S. Marines whose ages ranged from 18 to 25 years.

The friendly and enemy target set in each trial was a 24-target scenario that used friendly (white circular marking on the chest of the target) and enemy (olive drab green) E-type silhouette targets. Half of the targets were friendly and half were enemy. Ranges consisted of 50, 100, 150, 200, 250, and 300 meters and all target exposure times were 4 seconds.

Analysis of variance analyses revealed significant differences for both math and SA tasks during shooting versus non-shooting (baseline) conditions. Additionally, multiple regression analyses yielded significant regression models for predicting performance, workload ratings, and stress ratings under certain conditions.

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1. Introduction

The dismounted soldier of the future will be "loaded" with more information processing tasks while he performs shooting tasks. It is conceivable that in the future, some increased level of cognitive tasking may be performed simultaneously with shooting tasks. The effect of shooting under cognitive load has not been studied to date. It is imperative the soldier not be overburdened mentally because that would result in decreased soldier survivability and lethality. This study was designed to address the workload issue that would be performed at the U.S. Army Research Laboratory's (ARL) small arms shooting performance research facility (SASPRF).

The Human Research and Engineering Directorate (HRED) of ARL is the Army's leader in studying shooting performance with small arms systems. The Warrior Performance Research Team of HRED's Dismounted Warrior Branch has a unique and highly regarded SASPRF, known as M-range, with which to collect human performance data during various live fire shooting conditions (see Figure 1).

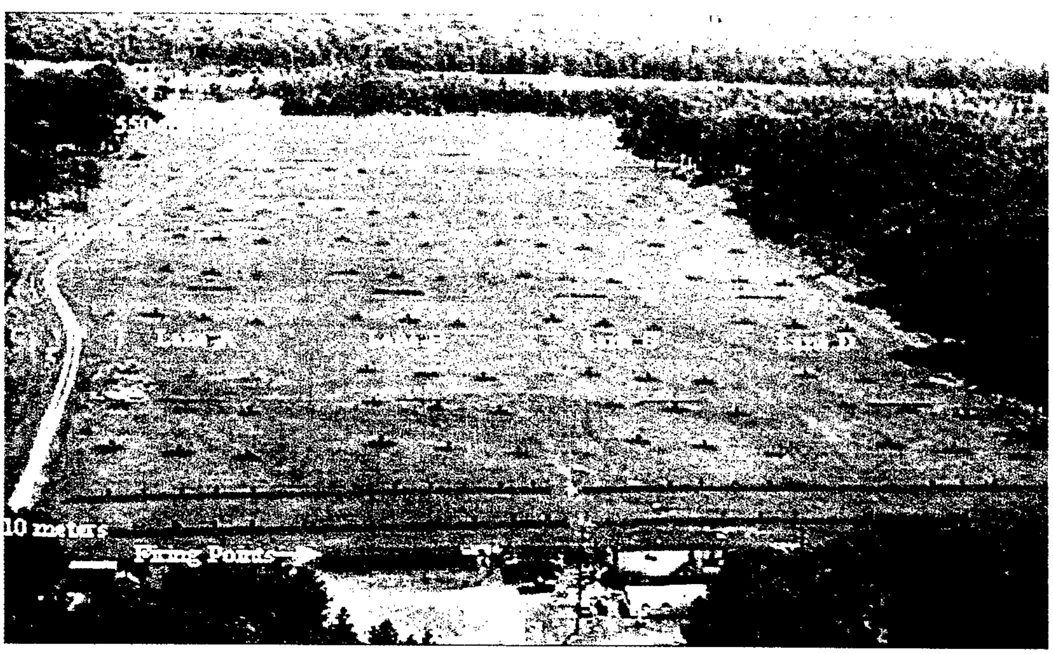


Figure 1. M-Range Small Arms Shooting Performance Research Facility.

This study was conducted to examine the ability of the soldier or Marine to perform various cognitive tasks while shooting. Additionally, this study examined the ability of soldiers or Marines to maintain the primary task of shooting pop-up friend-or-foe scenarios while performing secondary tasks of mathematical problem solving and situational awareness (SA) memory recall tasks. Finally, this study examined the effect of cognitive workload levels on the ability of soldiers to correctly make "shoot-don't shoot" decisions in a friend-or-foe target environment.

This study is relevant to the interests of the Army to enable future dismounted system designers (Land Warrior, objective individual combat weapon [OICW], and combat identification systems) to design for minimum cognitive disruption. The cognitively loaded dismounted soldier must respond efficiently and effectively to single and multiple hostile target scenarios on the battlefield while maintaining cognizance of several aspects of SA. These SA tasks could be of several contexts such as friendly and enemy positions; enemy movement or intentions; friendly unit movement or intentions; changes in objectives, terrain features, and relevant obstacles; and communications about non-combatants or neutral forces in the area of operations. The results may provide researchers in the Department of Defense, academia, and industry with information about the efficacy of information systems for small arms shooters.

2. Current Dismounted Systems and Trends in Dismounted Equipment Environment

The M16A2 is the current rifle issued to U.S. Army fighting forces. This is a relatively simple system to use and is used well by the soldiers serving in U.S. armed forces. The soldier carries and uses other equipment such as load-bearing equipment, body armor, ammunition and magazines, as well as communication equipment. The infantry soldier's job to date has been straightforward and free of high technology systems that could have increased the cognitive workload. However, the warrior's environment is changing in three distinct ways:

- The war-fighting environment is increasingly pointing toward urban or "built-up" areas (as seen in Haiti, Bosnia, and Somalia).

- The weapons the soldier will use are becoming more sophisticated (e.g., the air-bursting capability of the OICW).

- The information being provided to the soldier is increasing, thus allowing more SA cues and potential for overload, which could prove deadly in an engagement with the enemy.

These issues point to the emerging systems that provide the soldier with SA of terrain, friendly and enemy units, their movement and intentions. Newer dismounted systems such as Land Warrior XXI and the Marine's integrated infantry combat system propose concepts with which the soldier could have advanced communication, weapon connectivity, and other data at his disposal to fight more efficiently and with greater lethality (see Figure 2).

Figure 2. Land Warrior XXI Capabilities.

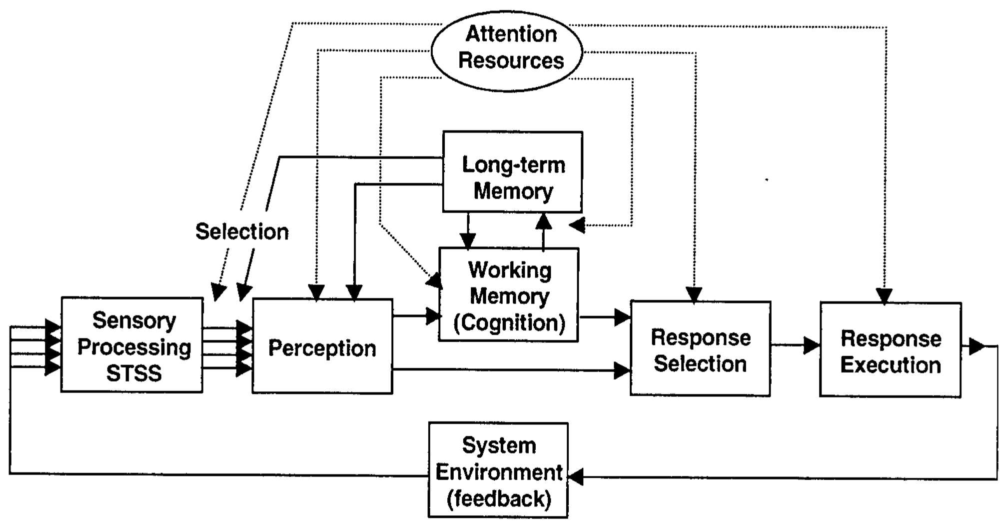
Additionally, soldier knowledge requirements and workload will increase because of the sophisticated weapon systems that will be fielded in the future (e.g., OICW). The last issue listed on page 2 is the critical issue with which this study is concerned.

The capability of this new system will provide (a) enhanced communication (squad radio and intra-squad communications), (b) enhanced navigational features, (c) weapon-sensor connectivity (to allow viewing of targets indirectly), and (d) other data access such as military occupational specialty (MOS)-related data or emergency medical information.

The Project Manager (PM) Soldier has made significant progress in bringing information in a meaningful way to the soldier, but the workload of using such a system (dual-task or multi-task environment) while having the burden of acquiring and engaging targets has not been assessed to date. This, in combination with a new, highly technical weapon system of the future, may bring failure in terms of soldier information processing ability, soldier task performance, and soldier lethality unless these systems are designed with the target population's capabilities, limits, needs, and environments in mind.

A human being has limited attentional resources. Systems must be designed so that critical information can be attended to when needed and so that non-critical information is not presented. Attentional resources of the war fighter must remain the center of focus for combat tasks that will require high levels of concentration and discrimination in future military operations in urban terrain environments.

One basic qualitative model of attentional resources as proposed by Wickens (1984) is illustrated in Figure 3.



STSS = short-term sensory store

Figure 3. Model of Attentional Resources (Wickens, 1984).

3. Models of Attentional Resources

Several theoretical models currently exist to describe the nature of human multiple task performance. The single-channel hypothesis (Telford, 1931; Craik, 1948; Welford, 1952) contends that when a person uses mental processes for one task, processes for another task must wait or be "put on hold" for the person to perform the original task. Kahneman (1973) stated predictions of the human attentional resource. His proposal was that there was a single undifferentiated pool of such resources. The postponement of needed mental processes accounts for decrements in performance under heavy workload (Gopher, 1993). Early experiments by Allport, Antonis, and Reynolds (1972) and Allport (1980) disproved the single resource theory of mental resources by examining performance under an auditory shadowing task combined with sight-reading music. Wickens, Sandry, and Vidulich (1983) also disproved single resource theory, finding advantages to cross-modal time sharing instead of intra-modal time sharing in a laboratory tracking experiment and a complex flight simulation.

Other theories include the structural bottleneck theory (Broadbent, 1958), which purports that the process that identifies stimuli and determines their meanings has limits. This theory also was improved to state that sensory stimuli first enter a sensory buffer and then are analyzed for physical features such as pitch,

locations, and intensities and are then made available to a selective attentional filter.

The unitary resource theory (Knowles, 1963; Moray, 1967; Kerr, 1973; Kiss & Savage, 1977; Kahneman, 1973) has been proposed to account for aspects of multiple task performance, which have not been adequately explained through the use of single-channel and simple bottleneck models. Kahneman (1973) also adds that performance decrements occur when concurrent tasks compete for access to the same structures.

The multiple resource theory, first outlined by Navon and Gopher (1979), claims that various sets of processing resources are used in combination for performing individual tasks. Each set of resources is assumed to have its own divisible capacity. If two or more tasks require the same set of resources, the capacity available to them is supposedly allocated in a flexible graded fashion, depending on task requirements.

Wickens (1984) has expanded these assumptions, suggesting a three-dimensional taxonomy of resources based on stages, codes, and modalities of processing. Wickens identified a number of possible resource capacity channels:

- Type of input and output modality (visual versus auditory input, manual versus vocal output),

- Code or representational format used by the operator (linguistic versus spatial code), and

- Stage of resource processing (encoding versus central processing).

Wickens also proposed that three factors would impact performance:

- Resource competition of the task(s),

- Amount of each type of resource available to be allocated to the task(s), and

- Relative efficiency of the resource allocated to the task(s).

The Wickens model of multiple resources appears to be the "best fit" of models available to describe the underlying processes in the experimental tasks performed in this study. The Wickens model of multiple resources will be used as the basic model for this effort since future efforts based on these data will be performed in a system that identifies separate processing resources.

4. Mental Workload and Dual Tasks

The process by which humans react to the dual-task paradigm is known as time sharing. The strategy of time sharing is used to perform tasks that are imposed simultaneously. Some of the differences in time-sharing ability may be attributable to practice or to basic time-sharing ability (Wickens, 1984).

Improved performance of a dual task can be said to be an increase in the automaticity of the task itself or of the increased time-sharing skills associated with practice (Damos & Wickens, 1980).

It has also been said that an improvement in single task performance will contribute to reduced resource demand for dual-task performance, based on improvement in single task component skills (Schneider, 1985; Schneider & Detweiler, 1988).

Cross-modality attention is the attention of resources to more than one sensory modality. In this case, visual and auditory attention was required. It is known that a redundant target code can accelerate processing time (Miller, 1991). Visual dominance is a concern because of the highly developed nature of the visual system (Jordan, 1972). The auditory task tends to suffer more performance degradation in relation to the visual task, as found by Massaro and Warner (1977). Note that auditory information is intrusive and is difficult to ignore, which is why it is used as a warning (Sorkin, 1987; Simpson & Williams, 1980).

5. Primary and Secondary Task Performance

The issue of mental workload (MWL) measurement is important when one is talking about the cognitive capabilities of the soldier. One of the methods for measuring MWL in the past has been the use of the secondary task. The secondary task is used as an additional load to the primary task (Rolfe, 1973; Ogden, Levine, & Eisner, 1979). The primary task method is based on the argument that increasing MWL will cause a performance decrement in either the secondary or primary task, depending on which task is to be maintained.

In this study, the primary task performance was emphasized. It is assumed that with three levels of secondary task difficulty, inferred differences in primary task demand would be apparent through the differences in secondary task completion. The secondary task in this case is a non-loading or subsidiary task

because the subject was instructed to avoid making errors in the primary task (friend-or-foe shooting task).

The secondary task is used to apply pressure on primary task performance (as in a future dismounted warrior system) during which, performance of more difficult tasks will deteriorate more than performance of easy tasks (Knowles, 1963). This is also a measure of how much additional work a soldier can undertake while still performing the task to meet system criteria. Samples of such secondary tasks include arithmetic addition, repetitive tapping, choice reaction time, and critical tracking tasks.

A secondary task (auditory input, verbal output) was employed that would not interfere with the channels used for shooting (visual input, psychomotor output). A primary-secondary task set was developed to maintain the least amount of channel interference and the best ability to time share among tasks, thus creating the least conflicting type of dual-task scenario, with the least amount of resource conflict. This would provide the least severe and most conservative conditions. This has been demonstrated in a paper by Wickens and Liu (1988).

The two types of secondary tasks used in this study "exercise" the Wickens model (seen in Figure 4) in two distinct ways. The first method employs mathematical problems that are first received into the short-term sensory store (see Figure 3) and are then perceived and calculated; a verbal response is then provided. The second method employs an SA memory recall task that required no immediate response except listening to and memorizing "radio-like" messages for the entire shooting trial, which required rehearsal until responses could be recorded. The input and output modes of primary task and secondary tasks are listed in Table 1 in terms of the Wickens (1984) multi-dimensional model of multiple resource theory.

Table 1. Primary and Secondary Task Properties

Task	Input modality	Code format	Output modality	Resource stage
Primary				
Shooting	Visual	spatial	manual	encoding
Secondary				
Math tasks	Auditory	verbal	vocal	central processing
SA memory recall	Auditory	verbal	vocal	encoding (rehearsal)

Upon completion of the trial, the subjects were asked to provide graphic responses on a map of their surroundings to re-create the data heard from their short-term memory.

The difference between the performances obtained for the three levels of secondary tasks will be used as the index of workload imposed by the primary task.

It is argued that analysis of primary task performance under low to moderate workloads is not sensitive enough to reveal effects (Kantowitz & Sorkin, 1983). A pilot study was performed in which four levels of secondary tasks were presented to the shooter. Three levels were chosen from the four, which adequately spanned the range of easy to difficult tasks while we tried to avoid floor and ceiling effects.

6. Measuring Workload on a Subjective Scale

The first method of measuring subjective workload was by the use of a modified Cooper-Harper scale that showed sensitivity in tasks that had cognitive and perceptual components. Recently, both the National Aeronautic and Space Administration (NASA) Task Load Index (TLX) and the Subjective Workload Assessment Technique (SWAT) gained recognition as valid measures of subjective mental workload. They are both multi-dimensional, TLX having six sub-scales and SWAT having three. SWAT is the most frequently cited workload analysis tool in the literature and was developed at the Air Force Armstrong Aero Medical Research Laboratory (AAMRL). SWAT, which is grounded in a multi-dimensional view of time load, mental effort, and psychological stress, has a background of extensive laboratory and field use. SWAT was selected for this study because of the rapid nature by which subjective ratings could be collected over many experimental trials. Additionally, SWAT has been validated with the use of general mathematic problem-solving ability (one of the secondary cognitive tasks used in this study).

7. Shooting and Marksmanship Research and MWL

The literature has much pertinent shooting data about various types of weapon configurations, styles of training, and various conditions for both novice and elite sport shooters and soldiers. However, no literature in the past has tried to quantify the MWL of a soldier while he was shooting or to quantify the limits of a secondary task while a soldier was shooting. This should be especially

important to the designers of future dismounted warrior systems who expect the systems to be used serially (system task, then fighting task, then back to the system) or simultaneously (the system will be accessed for pertinent information while the soldier is engaging targets).

7.1 Shooting Scenario

There has been some research about the effectiveness of known-distance (KD) shooting versus pop-up target shooting. Carey (1990) found that the correlation between KD scores and pop-up target scores was only 0.2. The live fire pop-up scenarios more closely resemble combat shooting scenarios than do standard Army qualification tests or KD.

In addition to the pop-up scenario, a friend-or-foe decision has been added to this shooting task to provide a more realistic mental burden to the shooting task. Twelve of 24 pop-up targets have a 6-inch white circle at their centers to identify them as friendly, causing a desired "don't shoot" decision (see Figure 4). Targets without white circles were designated as enemy targets that were to be fired upon (see Figure 4).

Figure 4. "Friendly" and "Enemy" Targets.

The 6-inch white circle was chosen instead of other colors and shapes because of its visibility at 300 m. Before the study, United Nations "blue helmets" were simulated as a friendly color but were discarded because they lacked visibility at even medium ranges (150 m) in various lighting conditions (sunny, backlit targets, and diffuse cloud cover). The "shoot-don't shoot" task was added because of the ever-increasing probability of encountering friendly, neutral, or non-combatants in the soldier's fighting environment. The targets were all exposed for a duration of 4 seconds and fell if hit before the 4 seconds expired.

7.2 Hypotheses

1. Shooting is a mentally demanding task that is quantifiable, and secondary task performance decrements will exist even at low levels of secondary task workload.

2. The ability of soldiers to perform cognitive tasks while shooting will diminish with increased difficulty of those tasks, as measured by secondary task completion performance.

3. Soldier psychological stress and cognitive workload ratings will increase as a function of increased cognitive workload levels.

4. Increasing levels of cognitive workload will adversely affect a soldier's ability to discriminate friend or foe (shoot-don't shoot decisions) while he is shooting.

7.3 Objectives

1. To determine the ability of soldiers to perform cognitive tasks while shooting.

2. To determine if soldier psychological stress and cognitive workload ratings are affected by different levels of cognitive tasks while soldiers are shooting.

3. To determine if levels of cognitive workload affect a soldier's ability to discriminate friend or foe (shoot-don't shoot decisions) while he is shooting.

4. To quantify task abilities and workload of shooting and secondary tasks and both single- and dual-task paradigms. This would result in performance and SWAT rating data as well as multiple regression equations for these data.

8. Methodology

8.1 Participants

Participants were 16 male volunteers from the U.S. Marine Corps (USMC) Detachment of the Ordnance Center and School at Aberdeen Proving Ground, Maryland. Fourteen of the Marines were newly trained, having just completed basic training and Marine combat training. The remaining two Marines were from the USMC detachment noncommissioned officer cadre. MOS types were varied.

All subjects met requirements for 20/30 visual acuity, and all subjects were experienced with the M16A2 and had required minimum weapons qualification. Ages ranged from 18 to 25 years old.

8.2 Apparatus

8.2.1 Demographic Questionnaire

A demographic questionnaire (see Appendix A) was administered to collect age, gender, MOS, years in that MOS, experience with firearms, dominant hand, dominant eye, and most recent marksmanship qualification scores.

8.2.2 TITMUS® II Vision Testing Device

Subjects were screened for 20/30 both-eye visual acuity far distance with a TITMUS® II visual testing device. If visual criteria were not met, the subjects were excused from the study.

8.2.3 M-Range (Shooting Task, Primary)

The shooting task consisted of a 24-target pop-up scenario that used friendly (white circular marking on the chest of the target) and enemy (olive drab green) E-type silhouette targets. Half of the targets were friendly and half were enemy. Ranges consisted of 50, 100, 150, 200, 250, and 300-meter targets.

Target exposure time was 4 seconds, with a 1-second between-target interval. Soldiers were in a foxhole-supported standing position for all trials (see Figure 5). Appropriate hearing protection was worn at all times. M16A2 rifles with iron sights were used for this study. A safety briefing was given to each subject upon his arrival at the M-Range facility, including the proper use of hearing protection (standing operating procedure [SOP] 385-H-188).

8.2.4 Mathematical Problem-Solving Task (Secondary)

The mathematical problem-solving tasks consisted of an auditory message, presented through earphones, which the soldier processed and responded to before he heard a completion tone. The auditory task consisted of listening to a mathematical addition problem and verbally producing a response before an audible tone was used to create a uniform forced reaction time that did not require data analysis for reaction time—only for accuracy. The number of problems per shooting trial (20) was kept constant, but more difficult mathematical problems were used to create higher cognitive workload conditions. The range of problems included adding single digit numbers with a necessary carrying operation (difficulty level of 4), adding double digit and single digit numbers with a carrying operation (difficulty of 5), and adding two, two-digit numbers with carrying required (difficulty of 6). The number of math problems correctly solved was calculated to score this secondary task. Difficulty of the

mathematical problems was operationally defined by the number of digits (one per digit), operator (one), and carry operation (one).

Figure 5. Marine in Foxhole-Supported Firing Position.

8.2.5 Situational Awareness Memory Recall Task (Secondary)

The monitoring task consisted of military style "radio traffic" that was presented during the shooting scenario. Five messages varied in content to include two, three, or four units of information such as type of unit, direction, distance from the shooter, and direction of travel. Low level was the type of unit and direction, moderate level added the distance of the unit, and high level contained all four types of unit information (see Table 2).

Responses were solicited immediately after the shooting trial and after the subject put the weapon on "safe," cleared the ammunition from the weapon, and set the weapon down. Responses pertaining to all information heard were scored according to number of correct units of information (converted to percentage). The response sheet used for this task is presented in Appendix B. Responses indicated the shooter's ability to recall details relating to SA information in this secondary task.

Table 2. Components of SA Memory Recall Task Messages

Type of unit	Direction of unit	Distance	Direction of travel
Friendly	North	200 m	Toward you
Enemy	East	500 m	Away from you
Unknown	West	800 m	Stationary

8.2.6 Subjective Workload Assessment Technique (SWAT)

SWAT (Reid, Potter, & Bressler, 1989) was used to quantify soldier workload ratings during various conditions. SWAT has been validated with mathematical processing tasks of various levels for workload assessment. The reasons for using SWAT were

- AAMRL developed SWAT specifically to capture subjective workload estimations from pilots operating aircraft. It is a useful tool for estimating the system's effect on the pilot.

- SWAT has been shown to be the most useful of all the available tools for this type of application, when the goal is to assess the workload experienced by an operator in an existing system.

- SWAT provides a consistent semantic interpretation of its ratings, which is necessary for the modules that use resource model output.

The definitions of these dimensions are

- Time load is the amount of time pressure one experiences in performing the task.

- Mental effort load is the amount of attention and/or concentration required of a person to perform a task.

- Psychological stress load refers to the presence of confusion, frustration, and/or anxiety that hinders completion of a task.

The SWAT technique for measuring workload has two parts: scale development and event scoring. In scale development, a card-sorting exercise is conducted that is designed to determine the subjective conception of workload for each subject within the three dimensions. During this sorting task, a subject sorts 27 cards that represent all possible combinations of the SWAT dimensions. When the cards are arranged in an order representing the combinations of the dimensions

that the subject thinks describes the lowest workload to the highest workload combinations, a scale can be created that reflects the way a subject (or a group) perceives the concept of workload. This defines the mathematical model for combining the three elements into a single dimension of subjective mental workload or conjoint analysis.

During event scoring, the subjects rated the experimental conditions using the dimensions of SWAT—one set of ratings for each event. Once the events were rated, the workload for each experimental condition was derived. A sample of the event scoring SWAT form is provided in Appendix C.

8.2.7 Specific Rating of Events (SRE)

The SRE rating scale was used for assessing soldier global psychological stress. Fatkin, King, and Hudgens (1990) used this scale to aid in the assessment of firefighter stress levels. The SRE consists of a numerical scale from 0 to 100 to assess a soldier's stress at a specified point in time. An example of this form is given in Appendix D.

8.2.8 Weapons and Ammunition

The M16A2 rifle with iron sights and 5.56-mm M885 ball ammunition were used for this study.

8.2.9 Auditory Presentation of Information and Hearing Protection

Two compact disk players with miniature "ear buds" were used to present auditory cognitive tasks. Single hearing protection ear "muffs" were placed over the ears to provide adequate hearing protection while subjects were shooting.

It is important for the reader to understand at this point that the levels of difficulty for both secondary tasks were not categorical but were on the interval scale. For operational definitions of levels of difficulty for each secondary task, please see the previous sections describing these tasks.

The graphic depictions of data, however, use the labels 1, 2, and 3 to denote the low, moderate, and high secondary task levels.

8.3 Procedure and Methodology

A listing of independent and dependent variables is presented in Table 3, with the notation of primary, secondary, or dual task presentation.

As part of the pre-test procedure, participants were given a volunteer agreement affidavit that described the study and possible risks (see Appendix E).

Table 3. Independent and Dependent Variables

Task	Independent variables	Dependent variables
Primary and dual task	Not applicable	Shots, hits, reaction time SWAT, SRE
Secondary and dual task	Math or SA memory task	Secondary task completion SWAT, SRE
	Secondary task difficulty (low, moderate, or high)	Secondary task completion SWAT, SRE

Subjects were then screened for visual acuity with a TITMUS® II vision testing device. If visual criteria were not met, the subjects were excused from the study. Demographic data were collected and then the participants were asked to self-rate present baseline stress levels by using the SRE.

The subjects reported to M-Range to begin study participation. A safety briefing was given to each subject upon his arrival at the M-Range facility, including the proper use of hearing protection (SOP 385-H-188). All Marines first "zeroed" their weapons (see Figure 6). They then trained with three, 18-target pop-up scenarios, in which all targets were fired upon and with one 24-target friend-or-foe pop-up scenario in which friendly targets (white circles on targets) were not to be fired upon. This gave the subjects familiarity with the "shoot-don't shoot" aspect of the experimental trials (see Table 4).

Figure 6. Marines Zeroing Their M16A2 Rifles.

Table 4. Presentation Order of Experimental Conditions

Subject	1	2	3	4	1	2	3	4
		Trial Set A				Trial Set B		
1	BaseLine	Math L1	Math L2	Math L3	BaseLine	SA L1	SA L2	SA L3
2	Math L1	Math L3	BaseLine	Math L2	SA L1	SA L3	BaseLine	SA L2
3	Math L2	BaseLine	Math L3	Math L1	SA L2	BaseLine	SA L3	SA L1
4	Math L3	Math L2	Math L1	BaseLine	SA L3	SA L2	SA L1	BaseLine
		Trial Set B				Trial Set A		
5	BaseLine	SA L1	SA L2	SA L3	BaseLine	Math L1	Math L2	Math L3
6	SA L1	SA L3	BaseLine	SA L2	Math L1	Math L3	BaseLine	Math L2
7	SA L2	BaseLine	SA L3	SA L1	Math L2	BaseLine	Math L3	Math L1
8	SA L3	SA L2	SA L1	BaseLine	Math L3	Math L2	Math L1	BaseLine
		Trial Set A				Trial Set B		
9	BaseLine	Math L1	Math L2	Math L3	BaseLine	SA L1	SA L2	SA L3
10	Math L1	Math L3	BaseLine	Math L2	SA L1	SA L3	BaseLine	SA L2
11	Math L2	BaseLine	Math L3	Math L1	SA L2	BaseLine	SA L3	SA L1
12	Math L3	Math L2	Math L1	BaseLine	SA L3	SA L2	SA L1	BaseLine
		Trial Set B				Trial Set A		
13	BaseLine	SA L1	SA L2	SA L3	BaseLine	Math L1	Math L2	Math L3
14	SA L1	SA L3	BaseLine	SA L2	Math L1	Math L3	BaseLine	Math L2
15	SA L2	BaseLine	SA L3	SA L1	Math L2	BaseLine	Math L3	Math L1
16	SA L3	SA L2	SA L1	BaseLine	Math L3	Math L2	Math L1	BaseLine

A minimum of six targets hit was required in each of the first three trials. All subjects met training criteria.

Following training, all eight experimental 24-target trials were presented to the subjects, one baseline (no cognitive load) and three experimental (various cognitive loads) trials, per type of cognitive secondary task. The order of the experimental trials is presented as in Table 2. There were two types of cognitive tasks, for a total of eight experimental trials. These trials were counter-balanced to minimize learning and order effects. This was a repeated measures design.

Subjects were given a mandatory 10-minute rest period after every two trials. Following each trial, each participant's cognitive workload and stress levels were collected with SWAT and SRE (stress) data forms, respectively. Participants were then fully de-briefed and given a point of contact for monitoring individual performance or results of the study.

The trials took place during a two-week period from 7 August through 23 August 2000. All weather data specific for the research area are presented in Appendix F.

9. Results

All data were analyzed by a repeated measures analysis of variance (ANOVA). Tukey's Honestly Significant Difference (HSD) test was used as a *post hoc* analysis in which overall results deemed that further refinement of mean comparisons was necessary. The data for shooting were analyzed by a 1-by-4 repeated measures ANOVA. The cognitive tasks (math and SA memory recall), SWAT, and SRE data were analyzed via a 2-by-3 repeated measures 2-way ANOVA. The different ANOVAs were used because some of the data contained comparisons in which the workload levels of the two cognitive secondary tasks were not congruent. Because of the number of ANOVAs performed, a Bonferroni family-wise alpha correction was used to determine new alpha levels of statistical significance. None of the significant data were affected by these new alpha levels. Multiple regression analyses (see Appendix G) were also performed on the data sets to formulate prediction criteria for the tasks performed in this study.

9.1 Shooting Performance – Shot and Hit Data

No significant effects were found for the number of shots or hits by level of cognitive tasks (math or SA memory recall). The ANOVA data are presented in the F-test Tables 5 and 6. The data are shown graphically in Figure 7, which depicts the training data for shots and hits on the left and the experimental data on the right.

Table 5. F-Test Data for Numbers of Shots for
Math and SA Memory Recall Tasks

Condition	SS	df	MS	F	P
Math problem solving	6.79	3	2.26	0.70	.55
SA memory recall	6.06	3	2.02	0.79	.50

Table 6. F-Test Data for Numbers of Hits for
Math and SA Memory Recall Tasks

Condition	SS	df	MS	F	P
Math problem solving	7.16	3	2.38	0.89	.44
SA memory recall	6.44	3	2.15	0.53	.66

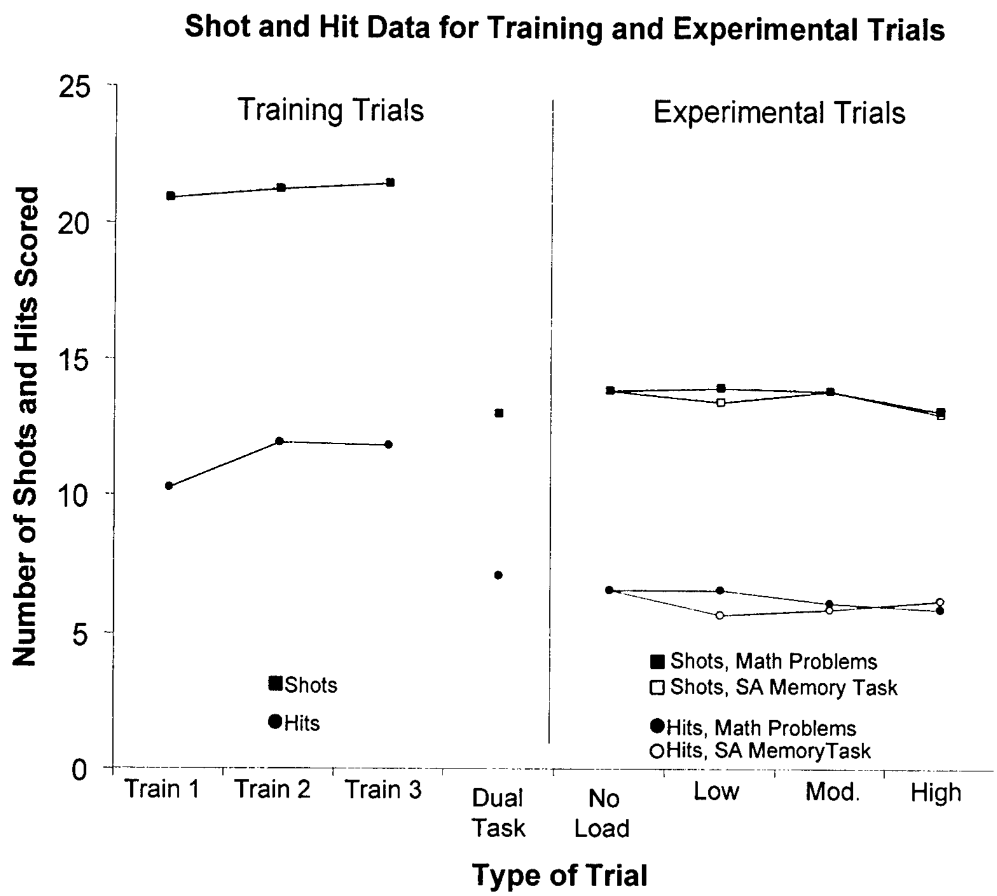


Figure 7. Shot and Hit Data for Both Training and Experimental Conditions.

The data on the left side of Figure 7 are three 18-target training trials, followed by a fourth 24-target friend-or-foe training trial.

9.2 Shooting Performance – Reaction Time Data

No significant effects were found for reaction time data. Reaction time data were only collected from shots that were scored as hits. All other reaction time data were considered erroneous because of extended time that could be used by the subjects after the target exposure time had expired. F-test data are presented in Table 7. The data are depicted graphically in Figure 8.

Table 7. F-Test Data for Shot Reaction Time for Math and SA Memory Recall Tasks

Condition	SS	df	MS	F	P
Math problem solving	.119	3	.039	0.76	.52
SA memory recall	.579	3	.193	2.07	.11

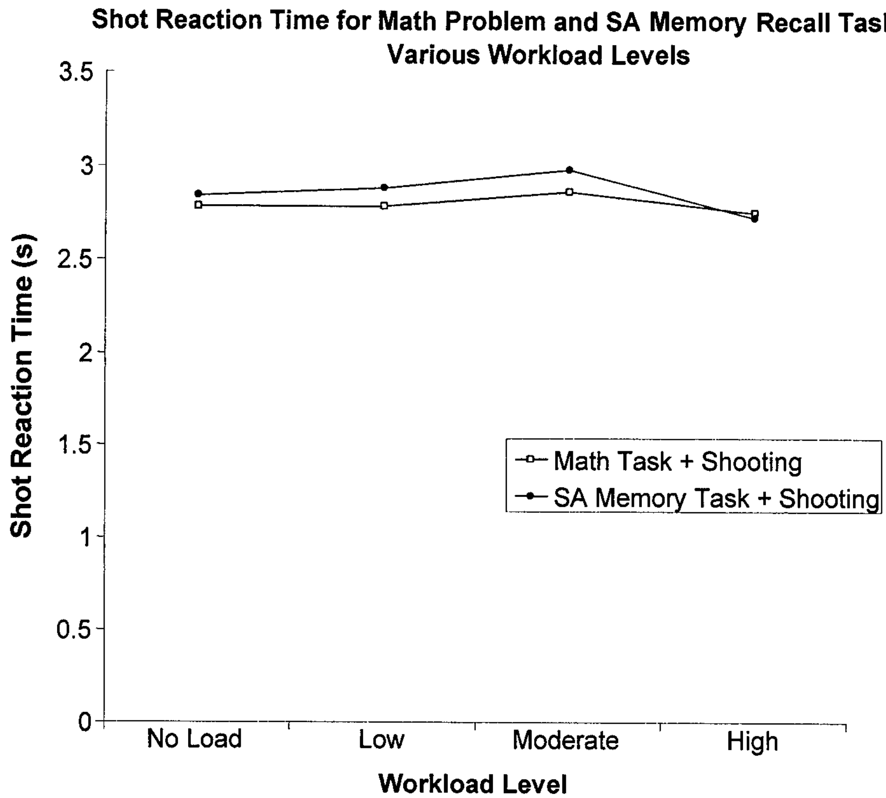


Figure 8. Reaction Time Data for Shots Scored as Hits.

9.3 Shooting Performance – Friendly Targets Engaged

Data for the number of friendly targets engaged during the 24-target shooting scenario were not statistically significant for either the mathematical problem solving or SA memory recall tasks. The F-test data are presented in Table 8.

Table 8. F-Test Data for Friendly Targets Engaged

Condition	SS	df	MS	F	P
Math problem solving	.422	3	.141	1.90	.143
SA memory recall	.000	3	.000	.	.

9.4 Math Task Performance

Significant task completion effects were found for only the simple effects of shooting and by level of math task difficulty. Tukey HSD *post hoc* tests revealed that all cells for the different math levels were significantly different from each other ($p < .01$). Statistically significant mean comparisons of interest have been identified with a dotted box around the measures for easy visual comparison.

The F-test data are presented in Table 9. The data are depicted graphically in Figure 9.

Table 9. F-Test Data for Math Task Completion

Condition	SS	df	MS	F	P
Math level x shooting	568.75	2,30	284.37	2.17	.131
Math level	61358.33	2,30	30679.16	106.81	.000
Shooting	9009.37	1,15	9009.37	41.91	.000

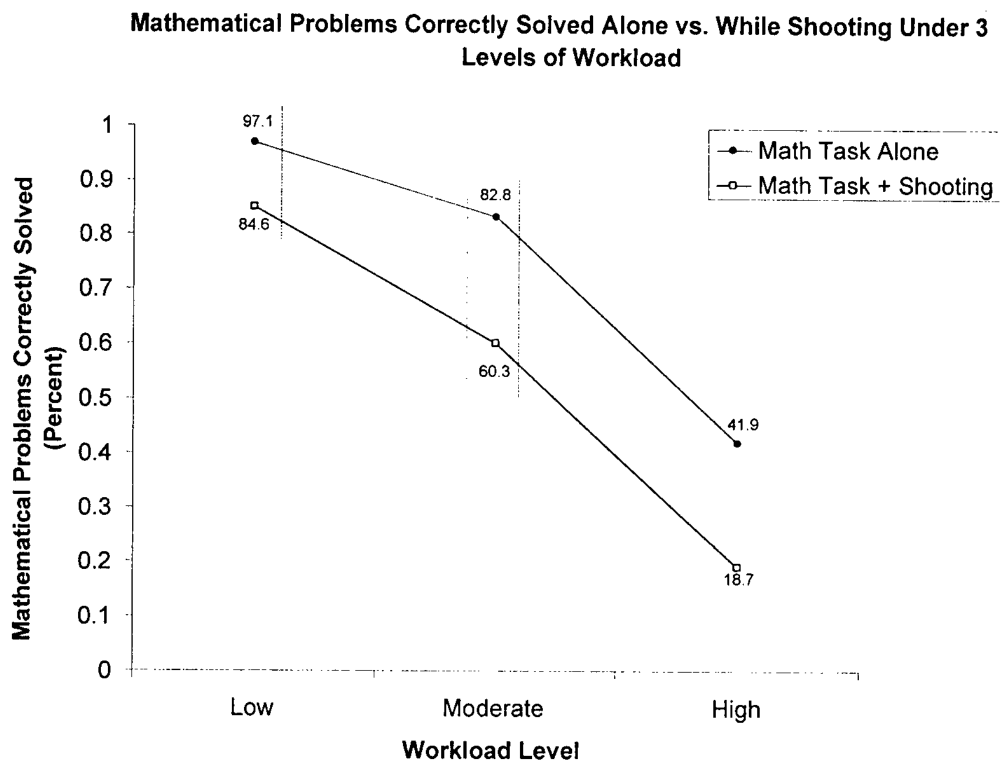


Figure 9. Baseline Versus Dual-Task Performance, Math Problems.

9.5 SA Memory Recall Task

Significant SA memory recall task completion effects were found for both the interaction effect of shooting or no shooting by level of cognitive task (SA memory recall task) difficulty and for both simple effects. Tukey HSD *post hoc* tests revealed that all cells for the different SA levels were significantly different from each other ($p < .01$). Statistically significant mean comparisons of interest have been identified with a dotted box around the measures for easy visual

comparison. The F-test data are presented in Table 10. The data are depicted graphically in Figure 10.

Table 10. F-Test Data for SA Memory Recall Task Completion

Condition	SS	df	MS	F	P
SA level x shooting	1051.58	2,30	525.79	9.46	.001
SA level	4074.08	2,30	2037.04	15.15	.000
Shooting	8140.16	1,15	8140.16	72.06	.000

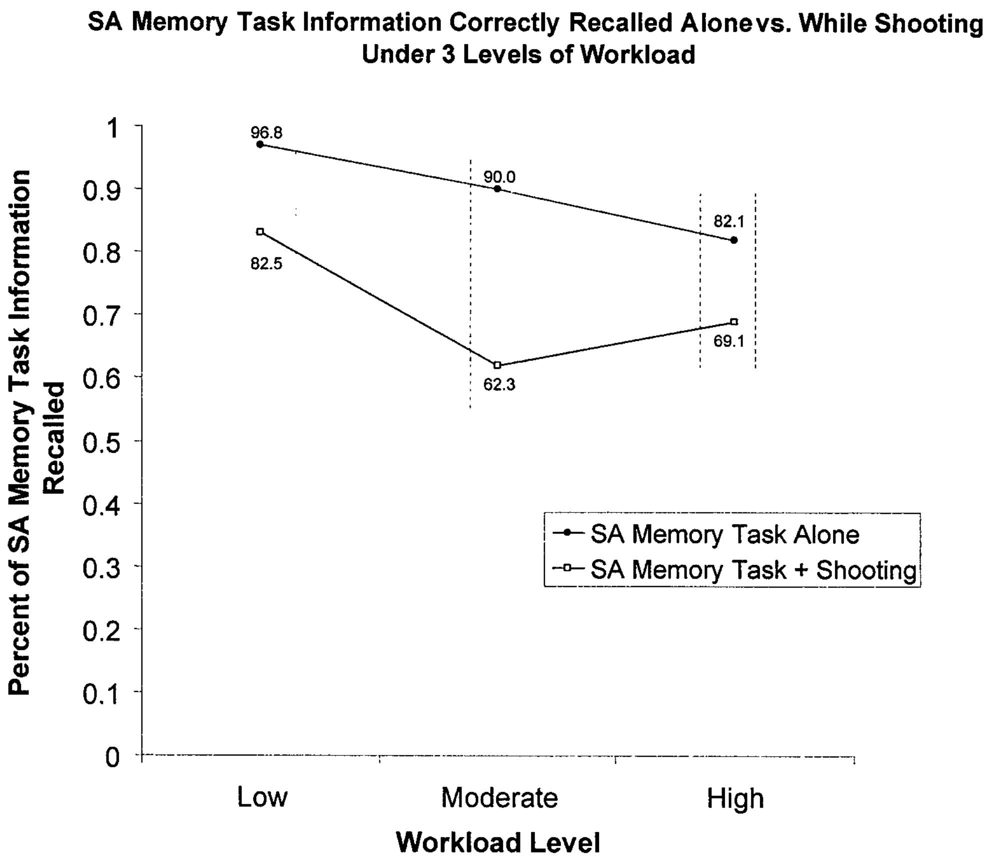


Figure 10. Baseline Versus Dual-Task Performance, SA Memory Recall Problems.

9.6 SWAT Ratings - Math Tasks

Significant SWAT ratings effects for were found for the interaction effect of shoot or no-shoot by level of math task difficulty and for both simple effects. Tukey HSD *post hoc* tests revealed that cell comparisons for the low and moderate math levels were significantly different from each other ($p < .01$). The difficult math task level is a homogeneous group. Statistically significant mean comparisons of

interest have been identified with a dotted box around the measures for easy visual comparison. The F-test data are presented in Table 11. The data are depicted graphically in Figure 11.

Table 11. F-Test Data for SWAT Ratings for Math Tasks

Condition	SS	df	MS	F	P
Math level x shooting	9953.77	2,30	4976.88	41.23	.000
Math level	3079.93	2,30	3079.93	10.32	.000
Shooting	49259.22	1,15	49259.22	62.14	.000

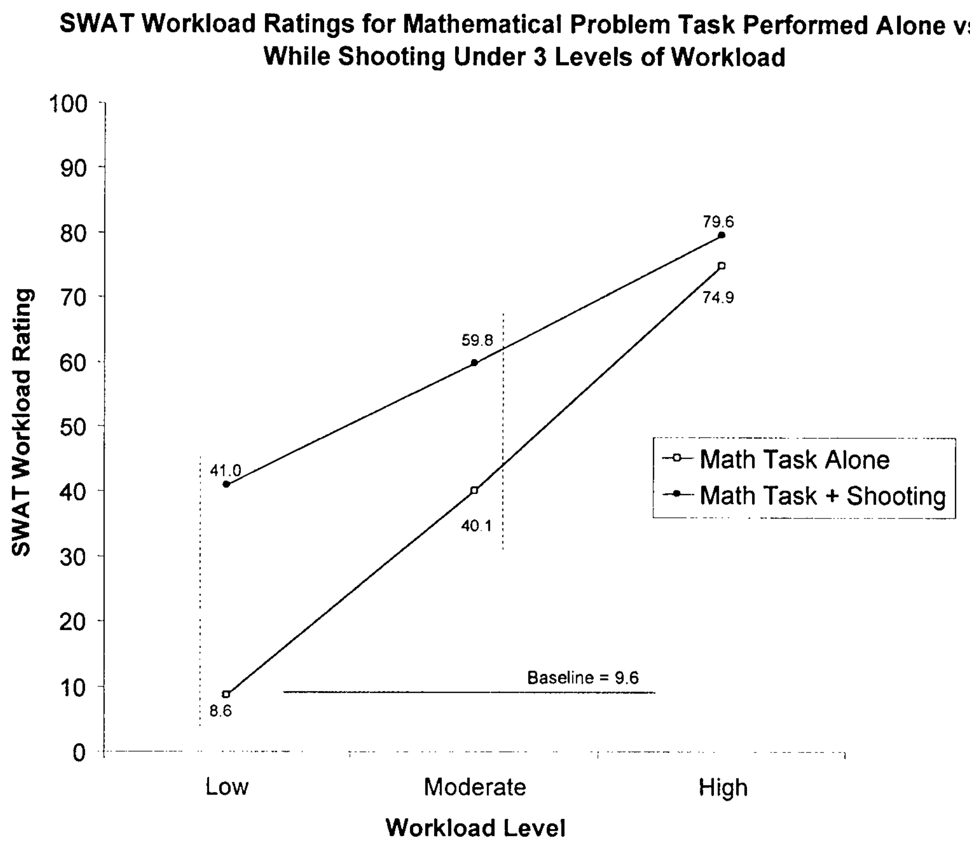


Figure 11. Baseline Versus Dual-Task Performance, SWAT-Math.

9.7 SWAT Ratings - SA Tasks

Significant SWAT ratings effects for were found for both the interaction effect of shoot or no-shoot by level of SA task difficulty and for both simple effects. Tukey HSD *post hoc* tests revealed that all cell comparisons for the different SA levels

were significantly different from each other (p < .01). Statistically significant mean comparisons of interest have been identified with a dotted box around the measures for easy visual comparison. The F-test data are presented in Table 12. The data are depicted graphically in Figure 12.

Table 12. F-Test Data for SWAT Ratings for SA Memory Recall Task

Condition	SS	df	MS	F	P
SA level x shooting	2302.80	2,30	1151.40	34.69	.000
SA level	11397.48	2,30	5698.74	7.35	.003
Shooting	20956.8	1,15	20956.86	19.68	.000

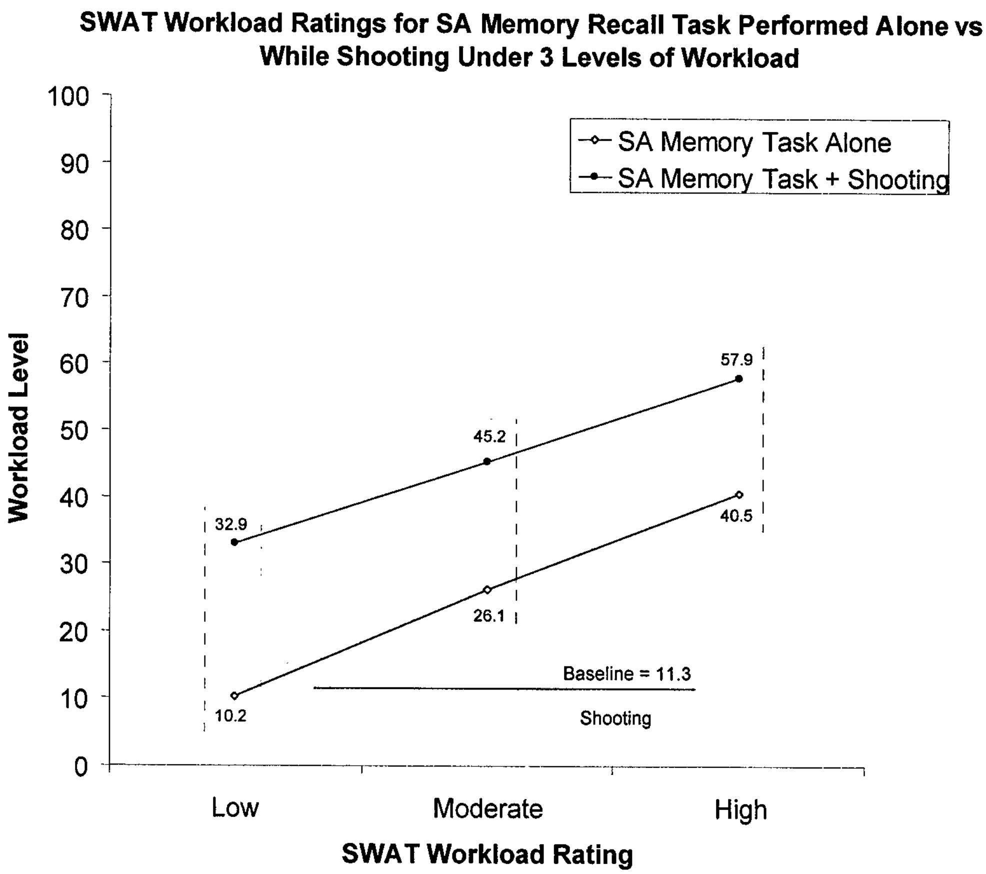


Figure 12. Baseline Versus Dual-Task Performance, SWAT-SA.

9.8 SRE Ratings - Math Tasks

Significant SRE ratings effects for were found for the interaction effect of shoot or no-shoot by level of math task difficulty and for both simple effects. Tukey HSD *post hoc* tests revealed that cell comparisons for the low and moderate math levels were significantly different from each other ($p < .01$, and $p < .05$, respectively). The most difficult math task level is a homogeneous group. Statistically significant mean comparisons of interest have been identified with a dotted box around the measures for easy visual comparison. The F-test data are presented in Table 13. The data are depicted graphically in Figure 13.

Table 13. F-Test Data for SRE Ratings for Math Tasks

Condition	SS	df	MS	F	P
Math level x shooting	9953.77	2,30	4976.88	41.23	.000
Math level	3079.93	2,30	3079.93	10.32	.000
Shooting	49259.22	1,15	49259.22	62.14	.000

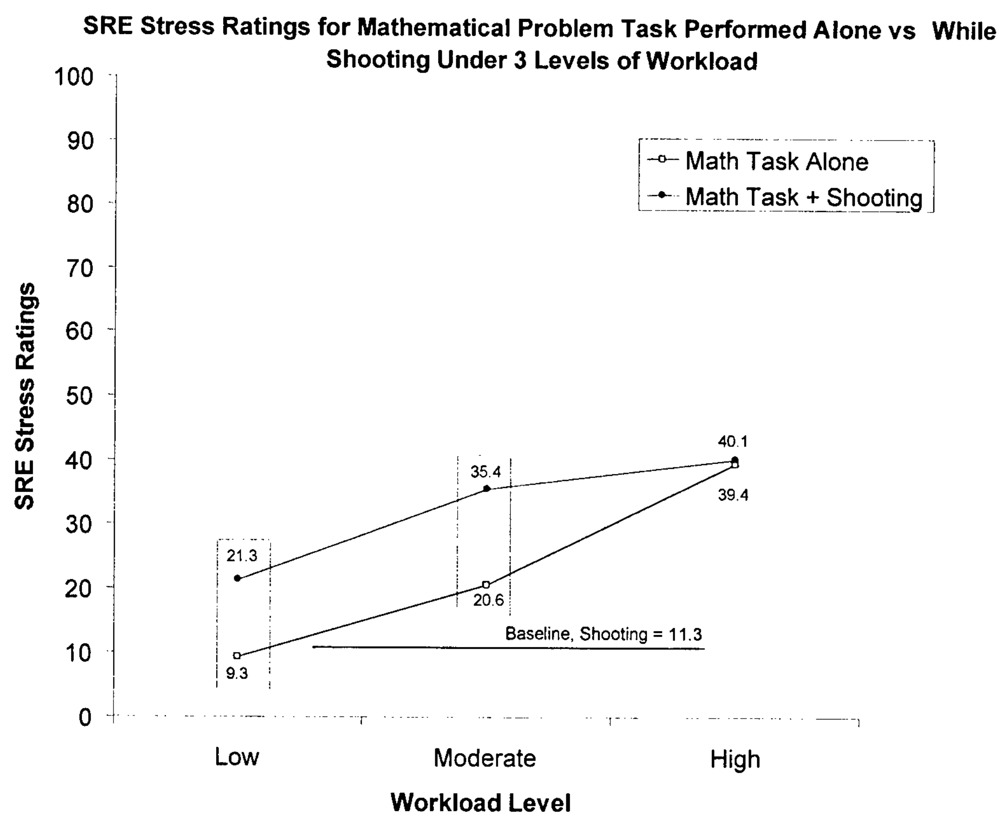


Figure 13. Baseline Versus Dual-Task Performance, SRE-Math.

9.9 SRE Ratings – SA Tasks

Significant SRE ratings effects for were found for the simple effect of SA level difficulty. The other simple effect simple and interaction effects were not statistically significant. No Tukey HSD *post hoc* tests were performed because of the non-significance of the variable of interest. The F-test data are presented in Table 14. The data are depicted graphically in Figure 14.

Table 14. F-Test Data for SRE Ratings for SA Memory Recall Task

Condition	SS	df	MS	F	P
SA level x shooting	148.56	2,30	74.28	1.53	.23
SA level	5822.02	2,30	2911.01	14.74	.000
Shooting	273.37	1,15	273.07	1.13	.30

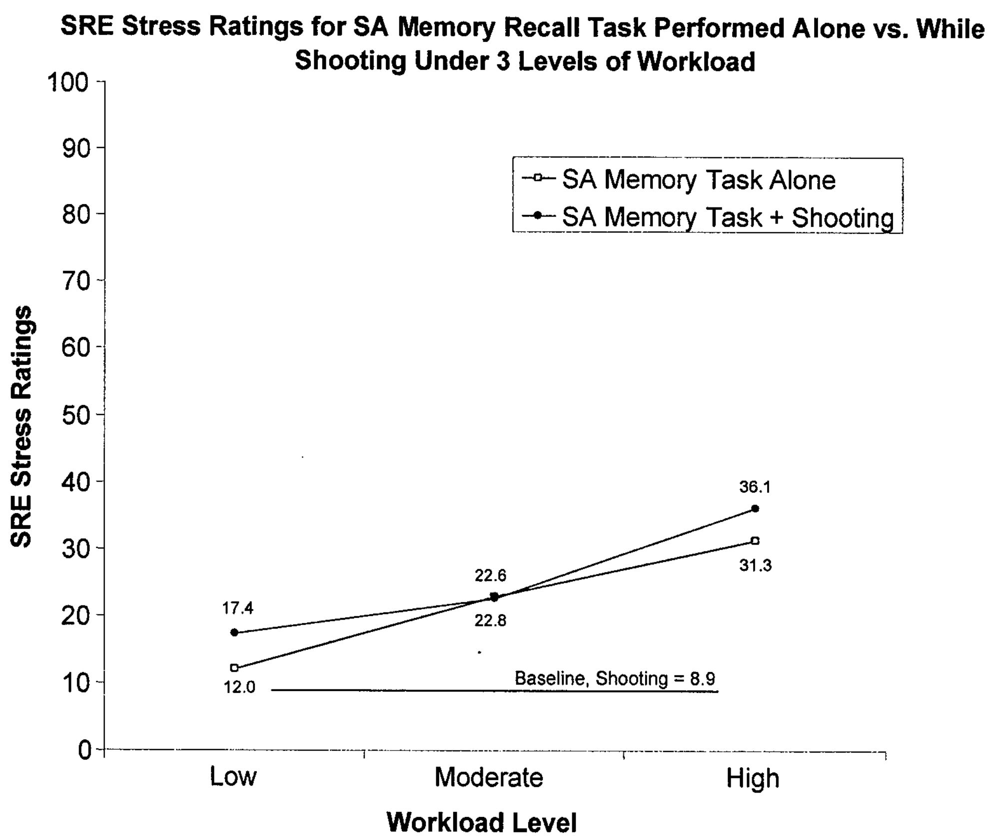


Figure 14. Baseline Versus Dual-Task Performance, SRE-SA.

10. Discussion

Stating the obvious conclusion (which is now supported by data), shooting is a mentally demanding task that places a burden on the attentional resources of the soldier. This was clearly demonstrated with the degradation of the two subsidiary secondary tasks that were imposed on subjects during this study in support of the work of Knowles (1963), Kahneman (1973), and Gopher (1993). The task of shooting does have a quantifiable workload, as measured with SWAT. The SWAT and SRE ratings followed a positive trend along with increased cognitive workload levels.

Increased levels of cognitive workload did not significantly affect a soldier's ability to discriminate friend or foe (shoot-don't shoot decisions) while he was shooting. However, some friendly targets were engaged. It is proposed that this issue be further examined and that more realistic constraints of target exposure time and target signature be addressed in future research.

Single-task and dual-task shooting paradigms have been examined in this study. Workload and stress ratings have been quantified in subjective terms as well as through the use of objective secondary task measures.

For the low and moderate levels of cognitive task difficulty, a time-sharing strategy was obviously used by subjects to cope with the dual-task scenarios supporting the work of Wickens (1984). The primary task was observed to apply pressure to the secondary task performance wherein performance deteriorated.

It appears from the data that the theoretical model of multiple resource theory can be supported from the nature of the data (Allport et al., 1972; Allport, 1980; Wickens, Sandry, & Vidulich, 1980; Wickens, 1984). It appears that for both types of cognitive tasks (mathematical processing and SA memory recall task), performance changes from not shooting (single task) to shooting (dual task) have, at a minimum, maintained performance differences from moderate to high levels.

10.1 Friend-or-Foe Shooting Discrimination Performance

Although not a significant finding in this study, some friendly targets were engaged erroneously by a small number of subjects. For future studies of this type, a reduced friendly target signature would be used that would require more discrimination processing time. The white marker on the friendly targets was useful because it could be clearly seen from 50 m to 300 m in all lighting conditions during the day. However, a shade of gray that would be slightly less

visible at 300 m would be useful to force more discrimination pressure into the friend-or-foe task. Target exposure times could be reduced from 4 seconds to 3 and 2 seconds. This would also add time pressure to the discrimination shooting decision event.

10.2 Shooting Performance (primary task)

The data clearly demonstrate that the primary task of shooting was maintained faithfully by the Marines during this study. Shot and hit data did not change significantly over all experimental trials for mathematical problem-solving tasks and SA memory recall tasks (see Figure 7). The performance of subsidiary secondary tasks did change and was affected by the difficulty levels of the secondary tasks. These findings support the work of Ogden (1979) and Knowles (1963). It is important to note that while the difficulty levels of the secondary task did show a progressive decrease, the change in performance between single-task performance and dual-task performance (during shooting) changed dramatically.

It is interesting to note for reaction time (RT) (shots scored as hits) that RT increased steadily for baseline through mid-cognitive load conditions. Although not statistically significant ($p = .11$), the data trends for both cognitive task data sets are startlingly similar. The data present a paradox between the performance of an individual and level of arousal (Yerkes & Dodson, 1908). This paradox is evident because the highest cognitive load level producing RT decreased *below* that of baseline (no cognitive load) (see Figure 8). The highest workload condition could have altered the level of subconscious processing from serial to parallel processing, thus demonstrating the effect of faster RT. Meyer and Kieras' (1997) work with the EPIC[1] model purport that parallel processing can be induced in certain conditions. It is also interesting to note that the SWAT workload and SRE stress ratings for this condition were not statistically different from each other, signifying a "saturation" level where the single task was not perceived as different from the dual task in workload level or stress. More investigation of this effect would be necessary to clearly define the underlying principles at work in this phenomenon.

10.3 Secondary Task Performance

10.3.1 Math Task

For the math task, completion level differences for shooting versus not-shooting changed from 12% (low) to approximately 23% for moderate and high difficulty levels, as can be seen in Figure 9 of this report. The error rate for moderate and difficult math tasks essentially doubles once the "moderate" and "difficult" difficulty levels are attempted during shooting. Under moderate and high levels

[1] not an acronym

of MWL, math task completion differences stabilized between the single (shooting) and dual task conditions with an approximate 23% change in both cases. The math problem-solving task proved to be the more sensitive of the two secondary tasks employed in this study.

10.3.2 SA Task

For the SA task, completion level differences for shooting versus not-shooting changed from 14% (low) to 28% (moderate) and stabilized again at 13% for (high) difficulty levels, as can be seen in Figure 10.

10.4 SWAT MWL Ratings

10.4.1 Math Task MWL Ratings

For the math task, workload differences for shooting versus not shooting changed by approximately 32% (low) to 19% (moderate), and to 5% (high). No statistical difference was observed for the comparison of shooting versus not shooting at the high level for the single and dual tasks. This phenomenon can again be explained by the notion that the high load condition has saturated the MWL rating, and the effect of additional perceived MWL shooting is lost at this level, as can be seen in Figure 11. The workload ratings for difficult math tasks essentially become identical at the high workload level.

10.4.2 SA Task MWL Ratings

For the SA task, workload ratings differences for shooting versus not-shooting changed from 23% (low) to 19% (moderate), to 17% (high) levels of difficulty. It appears in this case that the MWL ratings were essentially the same for differences between shooting and non-shooting conditions.

10.5 SRE Stress Ratings

10.5.1 Math Task Stress Ratings

For the math task, stress ratings differences for shooting versus not shooting changed from low (12%) to moderate (15%), and no statistical difference is shown at the high level of difficulty (5%). No statistical difference was observed for the comparison of shooting versus not shooting at the high level for the single and dual tasks. This phenomenon can again be explained by the idea that the high load condition has saturated the stress rating (much like the SWAT MWL ratings), and the effect of shooting is lost at this level, as can be seen in Figure 13. The SRE stress ratings for the high level of difficulty math tasks essentially become the same whether one is shooting or not shooting.

10.5.2 SA Task Stress Ratings

For the SA task, stress rating differences for shoot-or-don't-shoot decisions did not significantly change for any of the three levels of difficulty. It is thought that perhaps the psychological stress element of this task was not perceived by subjects to be a significant factor in workload, as demonstrated by the stress ratings.

10.6 Modeling Data

For the purposes of future performance, workload, and stress modeling work, multiple regression data for the various independent and dependent variables have been provided in Appendix G of this report. It is suggested that performance of a cognitive task alone (single task) and during shooting (dual task) conditions can be predicted with the data provided. Additionally, SWAT MWL and SRE stress ratings could be predicted. It is important to note that the tasks should be chosen carefully and that they would be similar in scope and difficult to apply the regression models.

Workload estimates, workload formulas, and task flow networks have been provided in Appendices H, I, and J, respectively. This information could be used in future workload modeling efforts to establish workload, general stress, or shooting performance in various conditions.

11. Conclusions

It is argued that future dismounted warrior systems be designed to provide minimal input, output, and central processing resource overlap (Wickens, 1984). It is further suggested that systems provide information to soldiers and Marines in a way that minimizes the requirement for time sharing between external tasks such as shooting and internal system tasks.

It is foreseeable that future warriors will be in situations where target engagement will be performed with a simultaneous need to attend to changes in mission. Such changes in mission could relate to potential catastrophic events involving revised information of friendly units, neutrals, or non-combatants in the area of operations or even orders to evacuate because of lethal environmental effects (friendly air or artillery strikes). Information should be categorized and presented appropriately for status (advisories, cautions, and warnings).

Sound human factors design of these systems dictates that soldier-systems be given appropriate analysis to identify high workload conditions and task flow

bottlenecks. Information should be as easy to access and process as possible. When possible, the use of both auditory and visual icons should be explored. When information cannot be presented as an icon, easy-to-understand visual presentation should be used to eliminate lengthy information processing requirements.

Because fratricide is more probable in conditions of high stress and workload, it is imperative that future warrior systems be assessed for workload demand on soldiers and Marines during all operational scenarios.

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APPENDIX A

DEMOGRAPHIC DATA FORM

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DEMOGRAPHICS AND EXPERIENCE QUESTIONNAIRE

Subject Number ____________

Age_____ Height ___ ft ___ in Weight _____lb

Rank______ Date entered military (month)______ (year)______

Primary MOS______ Secondary MOS______

1. When was the last time you qualified with the M16A2 rifle?

   ______ Month _____ Year

2. What is your current level of qualification as a rifleman based on the Army's or Marine's standard?

   ____expert ____sharpshooter ____marksman

3. Do you usually fire a rifle ____left handed or ____right handed? (Check one)

4. Do you use your ____left eye or ____right eye to aim a weapon?

5. Do you wear glasses or contact lenses when you shoot? ___ Yes ___ No (Check one)

6. Do you play video games or computer games?

____Yes ____No

7. How well do you play video games?

____Poor ____Below Average ____Average ____Above Average ____Excellent

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APPENDIX B

ASA MEMORY TASK DATA RECALL FORM

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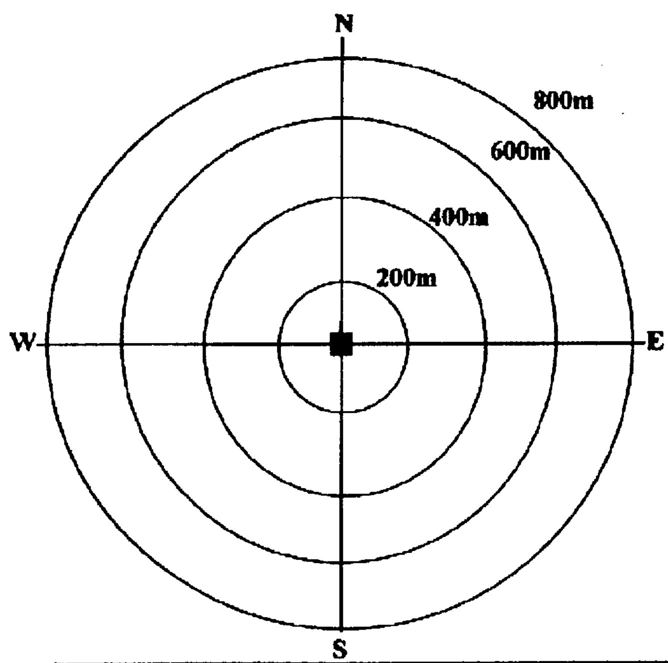
ASA MEMORY TASK DATA RECALL FORM

Situational Awareness Memory Recall Task

EXPERIMENTAL TRIAL

Subject ID___ Trial Number____ Level____



Key:

Unit Type:

(F) = Friendly

(E) = Enemy

(U) = Unknown

Unit Action:

Approaching = Arrow Towards Center

Moving away = Arrow Away from Center

Stationary = Box Around Unit

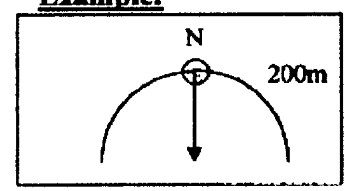
Unit Distance:

Place Unit Symbol at distance from center on the circle (200, 400, 600, or 800 meters)

Unit Direction:

Place Unit Symbol on direction axis North, South, East or West

Example:



Instructions:

There were 5 units presented during your trial. Please recall as much information about each of the 5 units on the map above, as correctly as you can, by using the map symbols in the key.

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APPENDIX C

SWAT EVENT RATING FORM

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SWAT EVENT RATING FORM

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

SUBJECT ID____________________ TASK ID____________________

(Mark an X in one choice for each of the three areas below that best describes what you believe the task workload to be.)

TIME LOAD

1 Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

2 Occasionally have spare time. Interruptions or overlap among activities occur frequently.

3 Almost never have spare time. Interruptions or overlap among activities are frequent, or occur all the time.

MENTAL EFFORT

1 Very little conscious mental effort or concentration required. Activity is almost automatic requiring little or no attention.

2 Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

3 Extensive mental effort or concentration are necessary. ery complex activity requiring total attention.

PSYCHOLOGICAL STRESS

1 Little consusion, frustration or anxiety exists and can be easily accommodated.

2 Moderate stress due to confusion frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.

3 High to very intense stress due to confusion frustration or anxiety. High to extreme determination and self-control required.

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APPENDIX D

SPECIFIC RATING OF EVENTS (SRE) FORM

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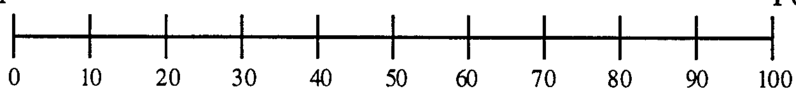
SPECIFIC RATING OF EVENTS (SRE) FORM

SUBJECT ID: ____________________ TASK ID: __________________

1. The scale below represents a range of how stressful an event might be. Put an "X" on the line to rate how much stress you experienced <u>during the previous experimental trial?.</u>

Not at All Stressful

Most Stress Possible



2. At what number value does the "X" touch the line? _______

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APPENDIX E

VOLUNTEER AGREEMENT AFFIDAVIT

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VOLUNTEER CONSENT FORM

U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD

Log No.: ________

Title of Research Project:	Study to Evaluate the Effect of Shooting Tasks on Cognitive Task Performance and Friend or Foe Discrimination
Principal Investigator:	David Scribner — Phone: (410) 278-5983
Location of Study:	Aberdeen Proving Ground, MD 21005

PURPOSE OF STUDY:

The purpose of this pilot study is to evaluate the effect shooting tasks have on cognitive task performance and friend or foe discrimination. Cognitive secondary tasks will be used to provide a secondary source or workload with which to measure performance changes while shooting. In the future, this type of information may be useful to designers of advanced dismounted warrior systems. We will look at how well levels of certain mental tasks can be performed while shooting in a shoot-don't shoot decision type environment.

PROCEDURE:

1. Prior to your participation in this evaluation, the experimenters will ask you if you have had an injury, are on profile or have a medical problem that would preclude your participation in this study. If you have a medical problem or are on profile that could put you at risk in this study, you will not be allowed to participate.

2. You will be requested to participate in this evaluation from 6 to 10 December 1999. During this evaluation you will be asked to perform zeroing and firing M16A2 rifle, cognitive tasks (such as a math and memory questions, stress and workload questionnaires. Your working schedule will be one day, 0800 to approximately 1130, or 1200 to approximately 1530.

3. During the day of the study, you will zero your M16A2, perform 5 training trials of pop-up target scenario shooting, and 7 trials of experimental shooting conditions. You will have a mandatory 10-minute break between sets of three trials. You will fire the M16A2 at M-range, and perform the cognitive tasks and stress and workload questionnaires. You will be given a safety briefing on the firing range. The experimenters will ensure hearing protection devices are properly used by all personnel when they are at the firing range.

5. You will be wearing BDUs.

6. Photographers will be taking pictures during this study. If you do not wish to have your photograph taken please inform the experimenters. If you agree to be photographed, steps will be taken so you will not be able to be identified in any published photograph or produced videotape.

7. At anytime during this evaluation you may withdraw without penalty should you decide to do so.

8. The risks that will be encountered in this evaluation are minimal and are typical of the everyday risks encountered by soldiers performing their duties. For the shooter performance evaluation portion of the study, the risks include possible slight shoulder bruising and exposure to short duration high intensity noise from automatic weapons firing. The experimenters will ensure hearing protection devices are properly used by all personnel when they are at the firing range.

Inclement Weather. If it is raining or snowing daily test activities will be delayed or canceled.

Reporting of Problems. The subjects will be instructed to inform the experimenters of any problems that occur during experimentation. They may be told to stop their activity until the problems are resolved.

9. All resulting data collected from you will be kept anonymous even when published in a report. Furthermore, you can have access to any of the data collected from you upon request.

Any published data will not reveal your identity. Your participation in this study is voluntary. If you choose not to participate in this study, or if later you wish to withdraw from any portion of it, you may do so without penalty. Military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human subjects. No administrative sanctions can be taken against military or civilian personnel for choosing not to participate as human subjects.

The furnishing of your social security number and home address is mandatory and necessary for identification and locating purposes to contact you if future information indicates your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this study. Information derived from this study will be used to document the study, to implement medical programs, to adjudicate claims, and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies. Collection of this information is authorized by 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087. Under provisions of AR40-38 and AR 70-25, volunteers are authorized all necessary medical care for injury or disease which is the proximate result of their participation in this study.

Your signature indicates you are at least 18 years of age, you have read the information on this form, you have been given the opportunity to ask questions, and they have been answered to your satisfaction, and you have decided to participate based on the information provided on this form.

<table>
<tr><td colspan="4">I do ☐ do not ☐ (check one and initial) consent to the inclusion of this form in my outpatient medical treatment record.</td></tr>
<tr><td>SIGNATURE OF VOLUNTEER</td><td>DATE</td><td>SOCIAL SECURITY NO.</td><td>DATE OF BIRTH</td></tr>
<tr><td>TYPED OR PRINTED NAME OF VOLUNTEER</td><td colspan="3" rowspan="2">PERMANENT ADDRESS OF VOLUNTEER</td></tr>
<tr><td>SIGNATURE OF TEST ADMINISTRATOR OR INVESTIGATOR</td></tr>
</table>

If you have questions concerning your rights on study-related injury, or if you have any complaints about your treatment while participating in this study, you can contact

Chair, Human Use Committee
Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD
(410)278-5800 or (DSN) 298-5800

Office of the Chief Counsel
Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1197
(301) 394-1070 or (DSN) 290-1070

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APPENDIX F

METEOROLOGICAL DATA

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METEOROLOGICAL DATA

		Wind Direct (ø)	Wind Speed (Mph)	Peak Wind Speed (Mph)	Air Temp (F)	Rel Humd (%)	Press (Ins)	Total Precip (Inch)
Date 8/7/00	Average	223	4.8	9.8	86	71	29.92	
	Maximum		6.2	12.7	90.2	87	29.93	
	Minimum		3.3	7.1	78.5	63	29.9	
	Total							0
8/8/00	Average	293	4	9.1	84.3	62	29.97	
	Maximum		5.1	12.7	88.7	92	29.98	
	Minimum		0.9	3.9	75	47	29.95	
	Total							0
8/9/00	Average	254	4.2	8.6	83.8	69	29.91	
	Maximum		5.4	11.1	89.5	94	29.93	
	Minimum		1.9	3.9	75.3	52	29.88	
	Total							0
8/10/00	Average	299	3.7	8.2	82.4	65	29.89	
	Maximum		5.7	12.2	86.4	77	29.9	
	Minimum		2.1	5.6	75.4	56	29.88	
	Total							0
8/16/00	Average	268	5.7	12.5	82.4	58	29.89	
	Maximum		8.4	17.7	86.9	93	29.9	
	Minimum		2	5	71.8	36	29.88	
	Total							0
8/17/00	Average	284	4.1	9.5	70.8	59	30.04	
	Maximum		4.9	11.3	75.3	74	30.07	
	Minimum		2.9	8.5	63.6	53	30	
	Total							0
8/23/00	Average	198	7.9	16.3	73.9	72	30.11	
	Maximum		9	19.7	76.3	82	30.17	
	Minimum		4.1	11.8	69.2	69	30.04	
	Total							0

Summary values are for the period 0800-1600EDT, each day.

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APPENDIX G

MULTIPLE REGRESSION DATA

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MULTIPLE REGRESSION DATA

Math Task Completion Prediction.

Ind. Var.	Met	df	F	sig.	Slope	Const.	r2
Cog. Load (L,M,H)	Lin	2,93	64.43	.0000	-29.43	219.78	.58
While Shooting (No,Yes)					-17.95	219.78	.58

SA Memory Recall Task Completion Prediction.

Ind. Var.	Met	df	F	sig.	Slope	Const.	r2
Cog. Load (L,M,H)	Lin	2,93	38.72	.0000	-7.45	119.50	.45
While Shooting (No,Yes)					-18.41	119.50	.45

Math Task SWAT Ratings Prediction.

Ind. Var.	Met	df	F	sig.	Slope	Const.	r2
Cog. Load (L,M,H)	Lin	2,109	49.10	.0000	12.95	-23.54	.47
While Shooting (No,Yes)					22.46	-23.54	.47

SA Memory Recall Task SWAT Ratings Prediction.

Ind. Var.	Met	df	F	sig.	Slope	Const.	r2
Cog. Load (L,M,H)	Lin	2,109	29.87	.0000	12.05	-21.92	.35
While Shooting (No,Yes)					26.19	-21.92	.35

Math Task SRE Ratings Prediction.

Ind. Var.	Met	df	F	sig.	Slope	Const.	r2
Cog. Load (L,M,H)	Lin	2,109	14.89	.0000	5.60	-4.87	.21
While Shooting (No,Yes)					10.91	-4.87	.21

SA Memory Recall Task SRE Ratings Prediction.

Ind. Var.	Met	df	F	sig.	Slope	Const.	r2
Cog. Load (L,M,H)	Lin	1,110	17.17	.0001	5.54	6.38	.13

Forward stepwise multiple linear regressions (p to enter and remove = .05) were performed using the following variables as possible predicters: Cognitive workload level (coded 1 = low, 2 = moderate, 3 = high) and Shooting condition (1 = shooting, 2 = not shooting). These analyses were run to predict secondary (math and SA) task performance, SWAT workload ratings, and SRE stress ratings. No values were missing, therefore none were replaced.

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APPENDIX H

MCCRACKEN-ALDRICH WORKLOAD SCALING OF TASKS PERFORMED

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MCCRACKEN-ALDRICH WORKLOAD SCALING OF TASKS PERFORMED

SINGLE TASK WORKLOAD ESTIMATES

Primary Task - Shooting Task (performed 24 times in 2 min, firing 50% of time)

	Visual	Cognitive	Auditory	Psychomotor	Total
Target Acquisition	7.0	3.7	0.0	2.6	13.6
Target ID (F/F)	3.7	3.7	0.0	0.0	7.4
Align Weapon Sights	5.0	4.6	0.0	2.6	12.2
Fire Weapon	5.0	1.0	0.0	2.6	8.6
Target Hit? (yes/no)	1.0	1.2	0.0	0.0	2.2
Target Still Up? (yes/no)	1.0	1.2	0.0	0.0	2.2

Secondary Task 1 – Mathematical Problems (performed 20 times in 2 min)

Listen to Problem	0.0	3.7	4.9	0.0	8.6
Calculate Answer	0.0	7.0	0.0	0.0	7.0
Tone Present? (yes/no)	0.0	3.7	1.0	0.0	4.7
Speak Answer	0.0	0.0	0.0	1.0	1.0

Secondary Task 2 – Situational Awareness (SA) Memory Recall (performed 5 times in 2 min.)

Listen to Message	0.0	3.7	4.9	0.0	8.6
Rehearse Information	0.0	6.8	0.0	0.0	6.8
Write Unit Info (Performed after trial)	(0.0)	(0.0)	(0.0)	(1.0)	(1.0)

DUAL TASK WORKLOAD ESTIMATES

Shooting + Math Task

Target Acquisition	7.0	3.7	0.0	2.6	13.6
Target ID (F/F)	3.7	3.7	0.0	0.0	7.4
Align Weapon Sights	5.0	1.0	0.0	2.6	8.6
Fire Weapon	5.0	4.6	0.0	2.6	12.2
Listen to Problem	0.0	3.7	4.9	0.0	8.6
Calculate Answer	0.0	7.0	0.0	0.0	7.0
Tone Present? (yes/no)	0.0	3.7	1.0	0.0	4.7
Speak Answer	0.0	0.0	0.0	1.0	1.0

Shooting + SA Task

Target Acquisition	7.0	3.7	0.0	2.6	13.6
Target ID (F/F)	3.7	3.7	0.0	0.0	7.4
Align Weapon Sights	5.0	1.0	0.0	2.6	8.6
Fire Weapon	5.0	4.6	0.0	2.6	12.2
Listen to Message	0.0	3.7	4.9	0.0	8.6
Rehearse Information	0.0	6.8	0.0	0.0	6.8
Write Unit Info	(0.0)	(0.0)	(0.0)	(1.0)	(1.0)

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APPENDIX I

TASK WORKLOAD CALCULATIONS FOR IMPRINT MODELING

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TASK WORKLOAD CALCULATIONS FOR IMPRINT MODELING

Math - Single Task Formula: V + C + A + P + N (number of tasks) = total workload for each task

Level 4 (L) = V + C (1.03) + A + P + N
Level 5 (M) = V + C (1.16) + A + P + N
Level 6 (H) = V + C (1.59)+ A + P + N

Math + Shooting - Dual Task Formula: V + C + A + P + N (number of tasks) = total workload for each task

Level 3 (L) = V + C (1.15) + A + P + N
Level 4 (M) = V + C (1.40) + A + P + N
Level 5 (H) = V + C (1.82) + A + P + N

SA - Single Task Formula: V + C + A + P + N (number of tasks) = total workload for each task

Level 4 (L) = V + C (1.03) + A + P + N
Level 5 (M) = V + C (1.10) + A + P + N
Level 6 (H) = V + C (1.18)+ A + P + N

SA + Shooting - Dual Task Formula: V + C + A + P + N (number of tasks) = total workload for each task

Level 3 (L) = V + C (1.17) + A + P + N
Level 4 (M) = V + C (1.36) + A + P + N
Level 5 (H) = V + C (1.33) + A + P + N

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APPENDIX J

TASK FLOW NETWORK FOR SINGLE AND DUAL TASKS

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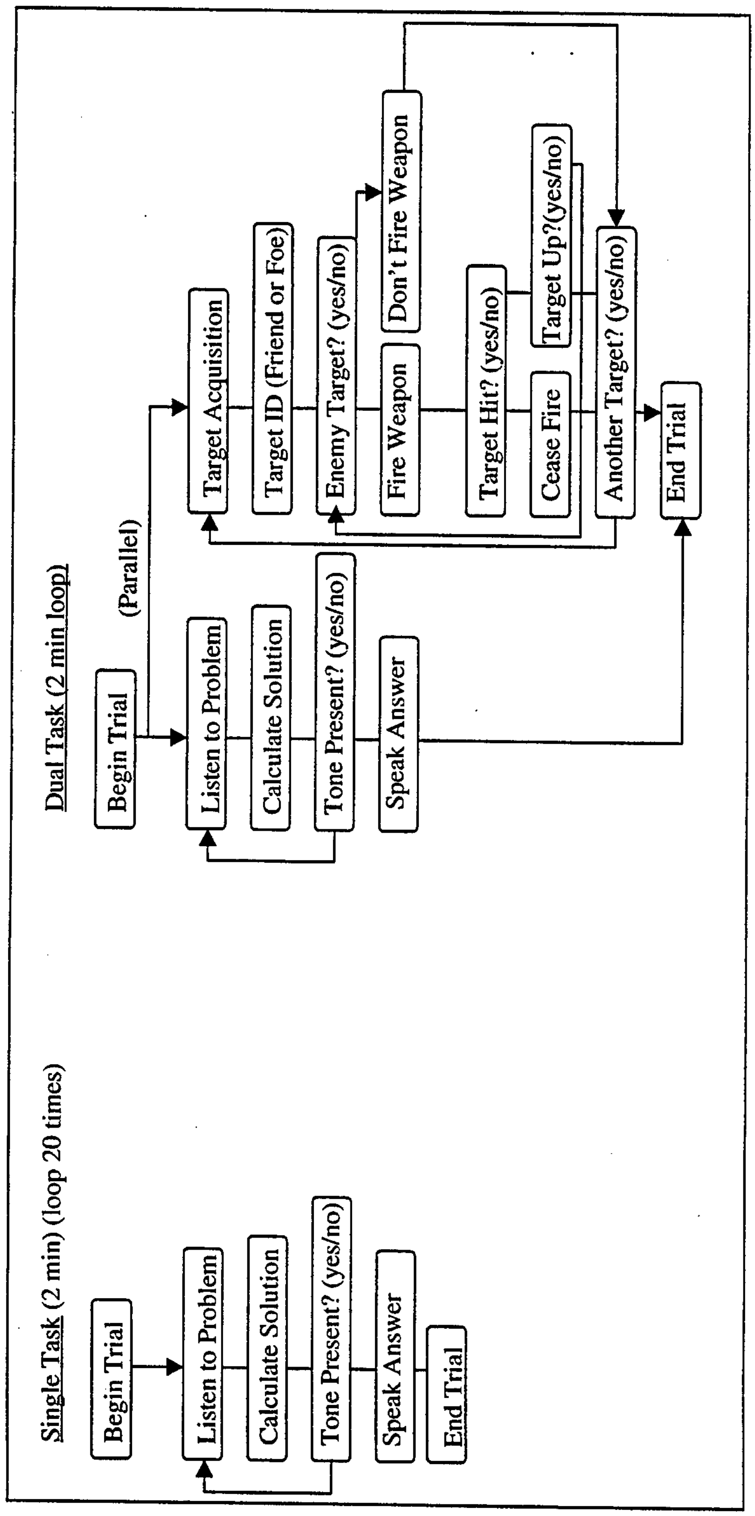
TASK FLOW NETWORK FOR SINGLE AND DUAL TASKS



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DEPARTMENT OF THE ARMY
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
ARMY RESEARCH LABORATORY
ABERDEEN PROVING GROUND MD 21005-5425

REPLY TO
ATTENTION OF

RDRL-HRM-B 12 June 2014

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: ARL-TR-2525, *The Effects of Mental Workload: Soldier Shooting and Secondary Cognitive Task Performance*, September 2001, by David R. Scribner

Replace previously published report with new report provided (new cover, notice, title, and SF 298 pages).

Reason: Report distribution statement has changed from limited distribution (B4) to public release (A).

David R. Scribner
MANPRINT Methods & Analysis Branch